Development of Autonomous Ride-on Mower Technologies

In North America's landscaping industry, chronic labor shortages and rising wages are boosting demand for labor-saving mowing solutions among professional gardeners.

To capture a larger share of the ride-on mower engine market, we are developing key technologies for autonomous models, focusing on supplying autonomous systems and suitable engines for professional ride-on mowers.

Introduction

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1 Background

With the ride-on mower market in North America recently expanding, we, like our competitors, are developing a variety of technologies to boost our sales volume and maintain the top market share. Thanks to our differentiating technologies, we currently hold the industry's top market share with an engine supply ratio of over 50% in the commercial ride-on mower market.

However, recent labor shortages and rising wages are driving increased demand for labor-saving mowing solutions among professional gardeners. In response to this, we believe that developing key technologies related to autonomous ride-on mowers and supplying autonomous systems and suitable engines will further expand our market share.

2 Overview of ride-on mowers

(1) Chassis overview

Figure 1 shows the chassis structure of a typical ride-on mower. **Table 1** lists its specifications. Its engine is

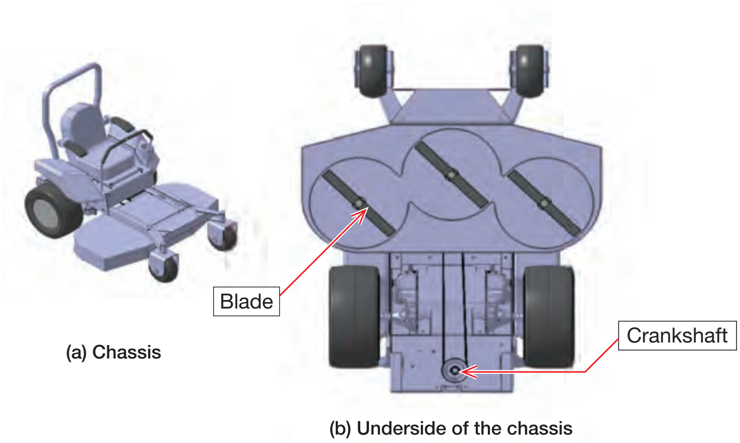


Fig. 1 Structure of a ride-on mower

Table 1 Specifications of a typical ride-on mower

Specifications of a typical ride-on mower	
Engine	Kawasaki FX820V
Displacement [cc]	822
Horsepower [hp] *Gross power	34. 5
Dimensions [mm]	2, 007 (L) ×1, 283 (W) ×1, 562 (H)
Mowing speed [km/h]	16

Fig. 2 Engine for lawn mowers: FX820V

shown in **Fig. 2**.

The ride-on mower cuts grass by rotating the blades attached to the underside of the chassis, as shown in **Fig. 1(b)**, via a belt connected directly to the engine's crankshaft pulley.

The engine is connected to hydraulic pumps, which move the mower by driving the right and left tires using generated oil pressure. The driving force to the tires can be controlled with the levers located to the right and left of the seat. The driver can move forward, backward, or turn the mower by manipulating these two levers with both hands. Tilting both levers forward moves the mower forward while tilting them backward moves it in reverse. You can change the orientation of the mower on the spot around its center (zero-turn) by pushing one lever forward and pulling the other back. This zero-turn capability is essential for ride-on mowers, which need to turn around with a small turning radius.

(2) Mowing procedure using ride-on mowers

Many families in North America have lawns, and since regular mowing is necessary to keep them looking beautiful, many homeowners hire professional gardeners for the job.

These gardeners typically arrive at the site in a truck loaded with a ride-on mower to mow the lawns.

Figure 3 shows conceptual images of mowing. Lawns are mowed to a consistent height in a uniform direction. In many cases, the mowing direction is maintained by turning the mower with a turning radius for a single mower once it reaches the end of the mowed area. Gardeners use ride-on mowers for wide, unobstructed areas and handheld mowers for trimming confined spaces, such as those between trees.

Since mowing a single location often takes less than one hour, professional gardeners can visit multiple sites each day to mow.

Fig. 3 Images of lawn mowing

3 Overview and benefits of autonomous operation

Mowing is usually done by a team of two or three gardeners. One or two gardeners mow the wide areas with ride-on mowers, while the other trims the edges.

The introduction of autonomous operation is expected to save labor for one gardener, because an autonomous mower can mow the wide areas while one gardener trims the edges and manages the autonomous mower, as shown in **Fig. 4**.

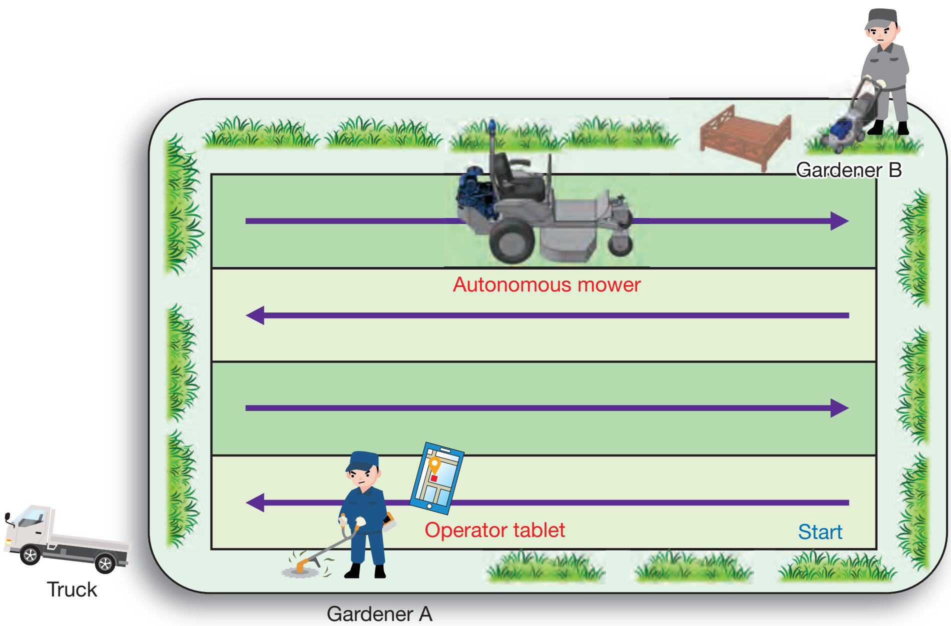


Fig. 4 Usage case for an autonomous lawn mower

4 Development of a chassis control technology specific to ride-on mowers

(1) Chassis modification for autonomous operation

Figure 5 shows an overview of the autonomous mower system. External commands from the autonomous driving control unit manage various operations, including engine start, acceleration, deceleration, turning, parking-brake setting, and engine stop. Additionally, the autonomous mower can switch between autonomous operation and manual driving[1, 2].

Before starting the autonomous operation, the mowing area and mowing direction must be specified remotely via a tablet computer. Once the tablet computer transfers the driving route information to the autonomous driving control unit, autonomous driving can begin. During autonomous driving, the mower follows the predetermined route while tracking its own location. The autonomous driving control unit calculates the mower's speed and turning direction based on it's current position and the target route information. GNSS antennas mounted on top of the mower gather satellite data for self-location and azimuth estimation. An inertial measurement unit (IMU) is also installed to calculate traction torque distribution according to the slope gradient and other factors, ensuring stable autonomous driving with little path deviation. The mower is also equipped with obstacle detection sensors, and is designed to pause, reroute, or perform other necessary actions to continue mowing once an obstacle is detected.

(2) Setting the driving accuracy

We collected driving data from professional gardeners while mowing to set the target driving accuracy for autonomous mowers.

Fig. 6 shows the driving track of a ride-on mower during mowing. The figure illustrates that the mower

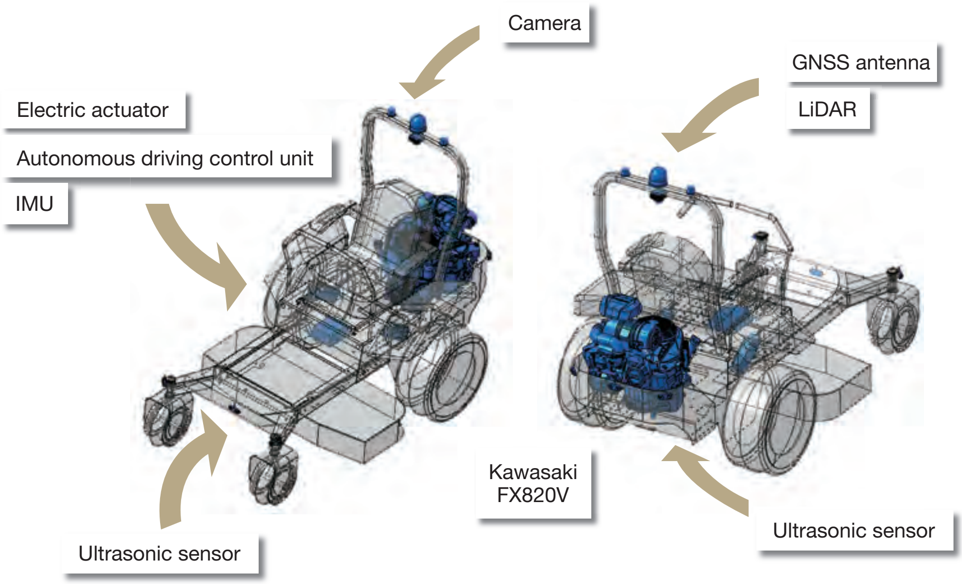
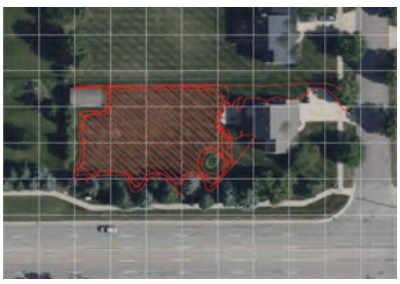
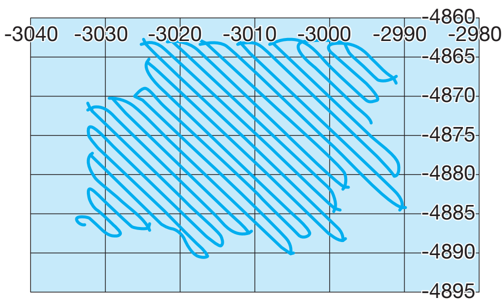


Fig. 5 Illustrated overview of the autonomous lawn mower



(a) Mower driving log



(b) GNSS coordinate data

Fig. 6 Logging manual driving data

thoroughly mowed the lawn by moving back and forth across the work area, repeatedly traveling from one end to the other. Stability during forward movement is crucial for achieving a beautifully finished lawn. Additionally, the mower must turn with a small turning radius of about 1.5 m to travel back and forth from one end to the other.

We set the mower's speed and tolerance for straight forward movement during autonomous driving based on manual driving to achieve a mowing accuracy and working speed equal to or higher than manual driving.

(3) Test drive

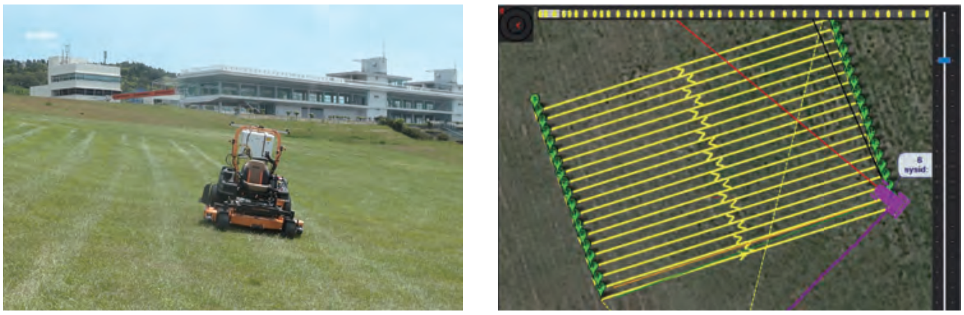
Figure 7 shows the autonomous lawn mower during a test drive. We conducted autonomous driving based on the same path plan as an actual mowing job on a lawn area to verify stability during straight forward movement, followability at the target mower's speed, stability on slopes, behavior during turn arounds, and operation in environments with obstacles.

5 Efforts to further enhance added value

(1) Synergy effects achieved through combination with our own engine

We are also working to enhance added value by integrating the autonomous system with our engine.

An autonomous system using our engine has a significant advantage: it can inherently utilize information from the engine control unit (ECU). For example, we believe that the fuel consumption rate during mowing can be calculated to set appropriate mowing prices, and the engine speed can be controlled to reduce work noise depending on the mowing environment. We are also



(a) Autonomous test drive (b) Mowing path plan

Fig. 7 View of the autonomous lawn mower during a test drive

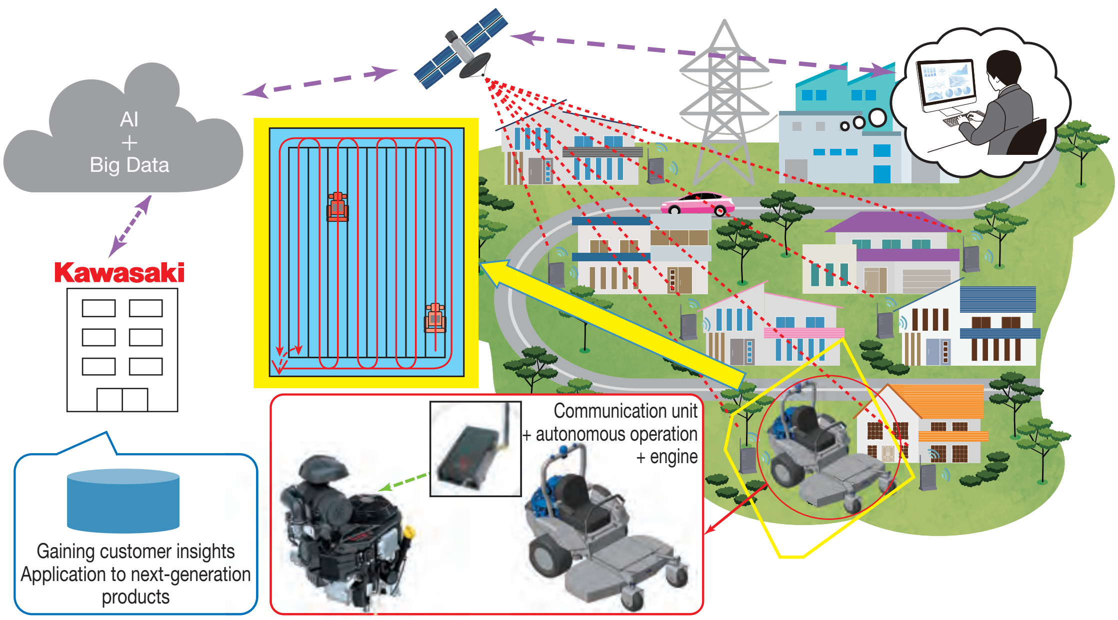


Fig. 8 Potential added value with our engine

Fig. 9 Beautiful lawn mowing patterns

considering incorporating a communication unit that supports external communication into our engine in the future, as shown in **Fig. 8**. This would allow us to consolidate operating data during autonomous driving in our cloud server, leveraging the data for business operations such as providing feedback for the development of next-generation products.

(2) Achieving well-designed lawn mowing patterns

Customers often request professional gardeners to create beautiful mowing patterns, as shown in **Fig. 9**. Creating these patterns requires tasks such as following complicated paths and varying the cutting height depending on position. In other words, it requires high skill levels to complete these patterns with manual driving.

In contrast, autonomous mowers can follow complicated paths if these are set in advance, allowing landscapers to create beautiful lawn mowing patterns easily and efficiently. Therefore, we are also developing key technologies to provide benefits to professional gardeners who adopt autonomous mowers.

Conclusion

We are developing autonomous technology for ride-on mowers to address chronic labor shortages in North America's landscaping industry. We will continue to focus on high-value development with the goal of maintaining our leading engine supply share in the commercial market.

References

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